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A SIMULATION ANALYSIS MODEL FOR CONTINUOUS SURFACE MINER AND TRUCKS OPERATION USING SLAM II

W.H. Griffin and J.K. Szymanski

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by

W.H. Griffin* and J.K. Szymanski**

ABSTRACT

A computer model has been developed to simulate the operation of the continuous surface miner (CSM) with trucks in open pit mines. Use of both the network modelling embedded in both discrete and continuous procedures provides sufficient flexibility and simplicity to evaluate the system's performance. The performance measure, the production rate, may be combined with the dollar values to estimate the system's performance. Stochastic simulation is used to reflect the random variation in duration of CSM and truck activities. Data was collected from an operating mine through time studies and analysis of production records. The maximum deviation of plotted durations of the cycle components from their theoretical values (chosen distribution) when tested by the stabilized probability plot method, showed Weibull distributions. These distributions were fitted to the various time elements of the truck and CSM work cycle. Validation against production data from the operating mine showed that the model satisfactorily described the system performance.

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*Associate Professor, University of Alberta, Edmonton, Alberta, Canada.
**J.K. Szymanski, Research Scientist, Coal Research Laboratories, CANMET, Energy, Mines and Resources, P.O. Bag 1280, Devon, Alberta, Canada, TOC 1EO

MODÈLE ANALYTIQUE DE SIMULATION D'OPÉRATIONS D'EXPLOITATION CONTINUE EN SURFACE ET DE CAMIONNAGE AU MOYEN DU SLAM II

par

W.H. Griffin* et J.K. Szymanski**

RÉSUMÉ

On a élaboré un modèle informatisé pour simuler l'exploitation du système d'extraction continue du minerai en surface (CSM) avec emploi de camions dans des mines à ciel ouvert. En appliquant la modélisation de réseau intégrée à la fois aux procédés discrets et continus, on assure une flexibilité et une simplicité suffisantes pour pouvoir évaluer la performance du système. Il est possible de combiner la mesure de la performance, c'est-à-dire le rythme de production, aux valeurs exprimées en dollars pour estimer la performance du système. On emploie la simulation stochastique pour représenter la variation aléatoire de la durée des activités d'exploitation minière en surface et de camionnage. On a recueilli les données dans une mine en exploitation, au cours d'études à long terme et d'analyses des diagrammes de production. L'écart maximum que montraient les durées reportées sur le graphique des composants du cycle par rapport à leurs valeurs théoriques (distribution choisie), quand on a cherché à

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*Professeur de falculté, Université de l'Alberta, Edmonton, Alberta, Canada.

**J.K. Szymanski, chercheur scientifique, Laboratoires de recherche sur le Charbon, CANMET, Énergie, Mines et Ressources, B.P. 1280, Devon, Alberta, Canada, T0C 1E0

les vérifier par la méthode de représentation graphique des probabilités stabilisées, se conformait aux distributions de Weibull. On a ajusté ces distributions aux divers éléments temporels du cycle d'exploitation des camions et d'extraction continue en surface (CSM). La validation des résultats vis-à-vis des données concernant la production de la mine exploitée a démontré que le modèle pouvait décrire de façon satisfaisante la performance du système.

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INTRODUCTION

The objective of the present study was to develop a model to simulate the operation of the CSM with trucks in an open-pit mine. In this CSM and truck haulage operation, several problems related to the best system utilization were of concern to decision makers:

1. The best assignment of trucks to the CSM,
2. The mine layout effect on productivity, and
3. A planning tool to estimate the expected production from a given continuous surface mining system with the CSM.

APPROACH

The model to simulate the operation of the CSM with trucks is intended for application to actual situations. Therefore, it was best to develop the model on the basis of a real-life problem. An operating mine contemplating the introduction of this computer model was chosen as the object of study.

The following approach was taken:

1. Collect operating time interval data on the truck and CSM operation at the mine in question. This includes time studies on components of the trucks and CSM work cycle and collection of information from production reports (time to failure and time to repair).
2. An analysis of collected data. This includes statistical analysis on the validity of the chosen distribution using the maximum deviation of the plotted durations of the cycle components from their theoretical values.
3. Formulate a simulation model of the mining operation using the CSM in which the stochastic character of the resource (CSM) and network activities (trucks) must be identified.
4. Validation of the model by comparing simulation results with production results obtained in actual operation.

COLLECTION OF DATA

This section deals with the collection and analysis of time data for subsequent use in the simulation model of the CSM and truck operation.

During the period of November 10-19, 1986, the Surface Mining Laboratory conducted a study of the CSM operations at the mine in question. The purpose of the study was to obtain and process consecutive activities data to model and simulate the mining operations with the continuous surface miner. The trucks and CSM were observed while being operated during the day shift of mining activities.

Two types of cycle times were monitored: CSM and trucks cycle times:

1. CSM CYCLE TIMES

The recording person was stationed inside the CSM cabin. During the study, the CSM operated in "circle cuts", "single cuts" and an "initial cut". Various cutting depths were used, the most common observed was 24 to 30 inches deep. A grader was also used in conjunction with the CSM to pile spilled coal, which was later picked up by the CSM. An initial cut took a longer time than a normal cut and picking up windrows created by the grader was done at a considerably higher speed than the normal cutting operation. At the start and end of each cut, the cut depth depends on the operator.

2. TRUCK CYCLE TIMES

The location of the operation during field work is illustrated in Figure 1. As shown, the coal cut by the CSM is hauled by trucks to the stockpile located outside the mining area.

Three Wabco-120C rear dump trucks with coal box capacity of 90t were assigned to the CSM during the field survey. (Fig. 2).

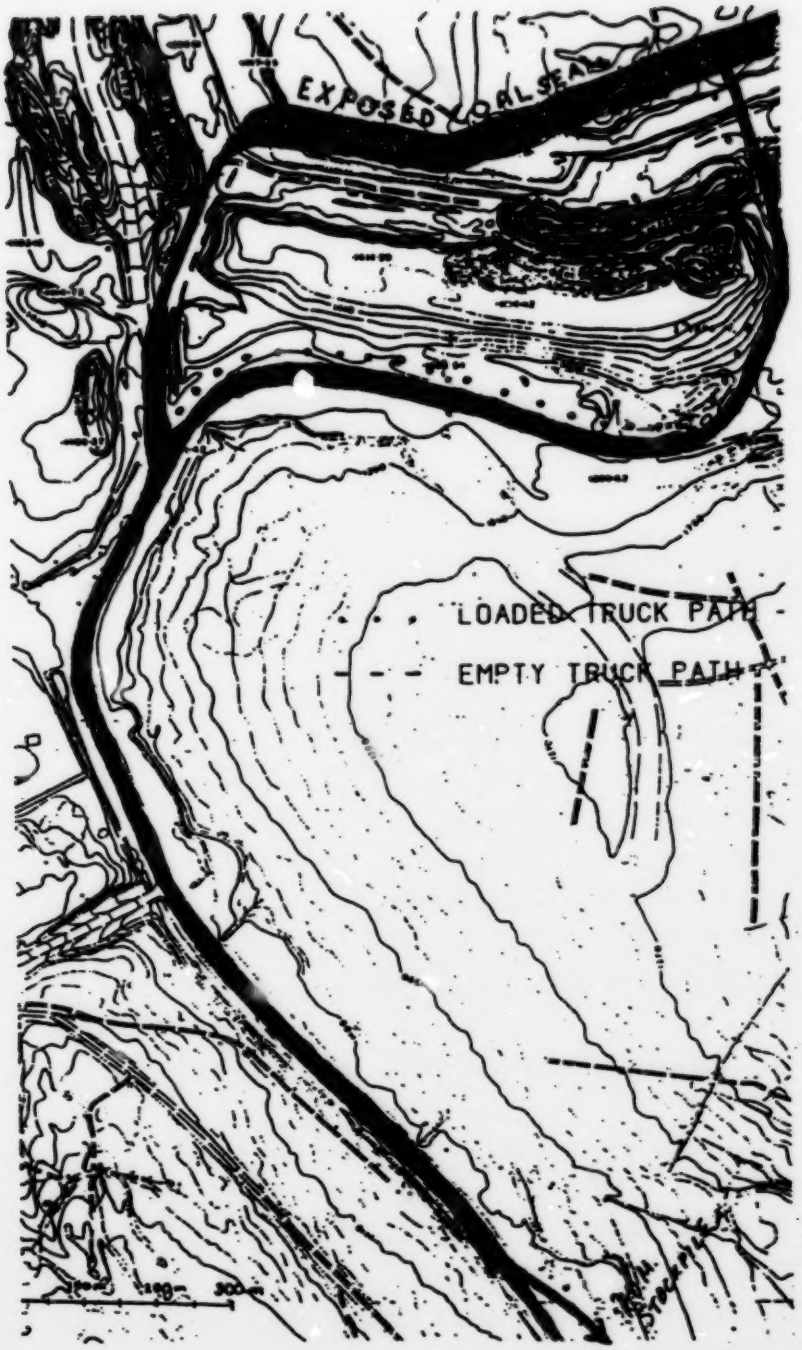


Fig. 1 - The location of CSM during field survey of mine in question.

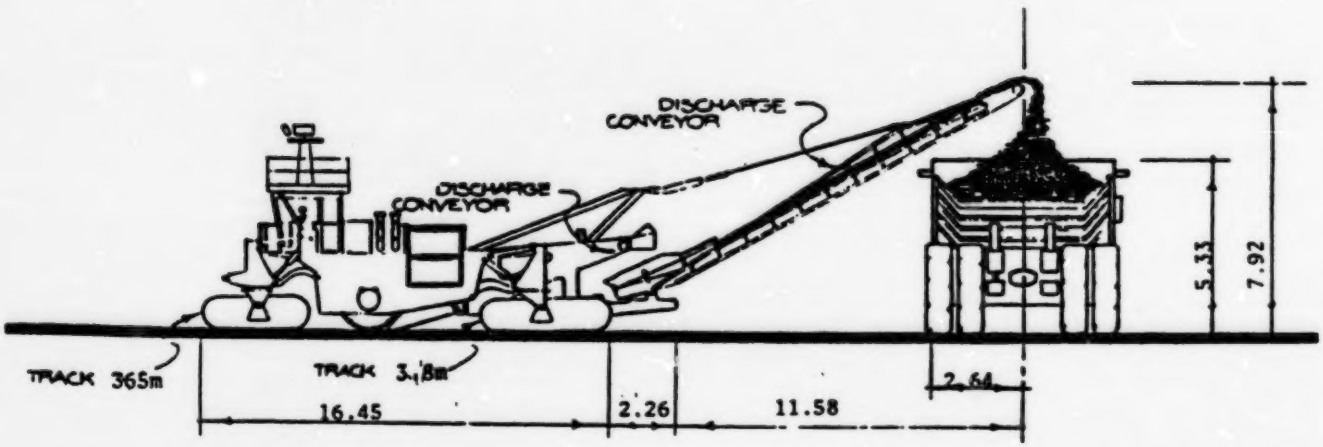


Fig. 2 - CSM loading Wabco truck.

Seven basic measurements were recorded for each cycle:

- time between trucks arrival,
- truck's queuing time,
- spot time,
- load time,
- haul time (full travel time),
- dump time,
- return time (empty travel time).

STATISTICAL ANALYSIS OF COLLECTED DATA

The collected cycle data was tested by comparing the cumulative frequencies of sample data with various theoretical models. By plotting theoretical cumulative frequency versus observed frequency, one measures the departures from the 45° line on the plot as relative goodness of fit with respect to a particular distributional model. When the particular arcsine scaling of the stabilized probability plot procedure is used the sample variances across the distributions are equalized and several distributional models can be visually and objectively compared for goodness of fit. The results showed that the simple Weibull or simple lognormal were equally good candidates. The Weibull model was chosen because of its greater flexibility.

Figures 3 and 4 show the stabilized probability plots of truck return times simulated from the lognormal and Weibull distribution.

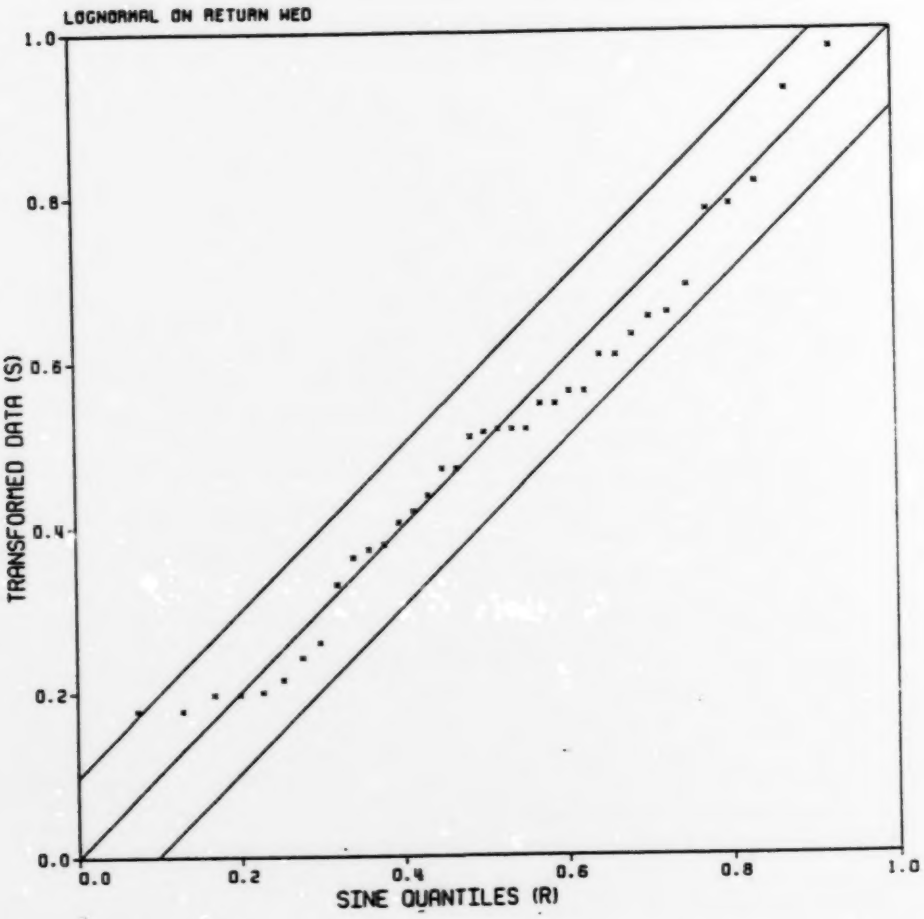


Fig. 3 Stabilized probability plots of truck return times simulated from the Lognormal distribution.

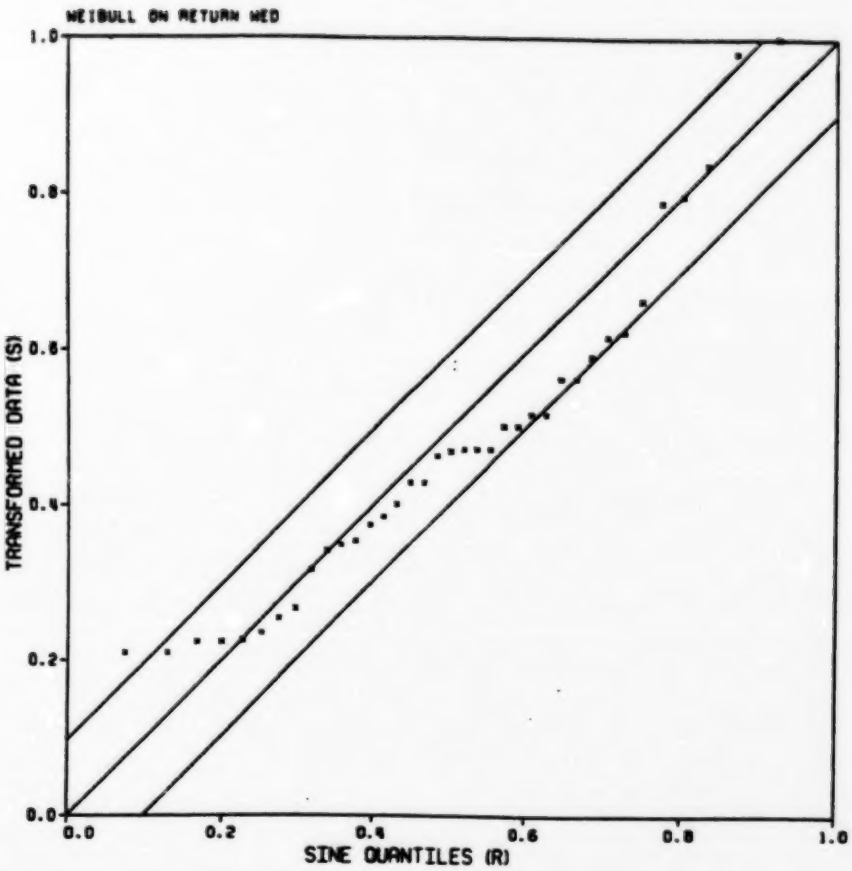


Fig. 4 Stabilized probability plots of truck return times simulated from the Weibull distribution.

A simple Weibull cumulative distribution function (c.d.f.) may be defined mathematically as follows:

$$F(t) = \begin{cases} 1 - \exp -(t/\eta)^{\beta}, & t \geq 0 \\ 0, & t<0 \end{cases} \qquad (1)$$

where:

$F(t)$	-	fraction of times less than a given value,
t	-	cycle time,
η	-	characteristic life or scale parameter,
β	-	slope or shape parameter, and
e	-	exponential.

The parameters η, β, are related to the mean and variance by the following relationship:

$$\text{mean} = \beta\Gamma(1 + {}^{1}/\eta)$$

$$\text{variance} = \beta^{2}\,[\Gamma(1 + {}^{2}/\eta) - (\Gamma(1 + {}^{1}/\eta)^{2}]$$

where $\Gamma(\ )$ stands for the gamma function.

Estimation of the Weibull distributions parameters from the time study data was done using an in-house developed program. The program estimates the parameters of a Weibull distribution by the rank regression and maximum likelihood technique. Table 1 shows the estimated Weibull distribution parameters for all components of truck and CSM time cycle. The plots of truck times probability density function (p.d.f.) are shown in Figures 5-9. Figure 10 shows p.d.f. of CSM turn-around times.

As systems observation time was too limited for meaningful collection of CSM failure data, these times were taken from shift reports. Tests on the validity of the chosen distribution shown that Weibull distribution may be used for these components. Figures 11 and 12 give the estimated density functions for the Weibull distribution obtained from the data.

Table 1 Estimates of Parameters of Cycle Times for CSM (Resource) and Trucks Network Characteristics of the Weibull Distribution.

TYPE OF ENTITY	CYCLE COMPONENT (MIN)	DISTRIBUTION PARAMETERS		MEAN (MIN)	STANDARD DEVIATION (MIN)
		BETA	ETA		
EASI-MINER	TURNAROUND	4.383	2.521	2.31	0.70
	TTR	1.45	200.46	103.51	2.80
	TTF	1.54	1524.65	11028.13	1.85
TRUCK	SPOT	2.252	0.491	0.30	0.35
	LOAD	5.165	5.015	4.65	1.28
	HAUL	12.189	5.058	4.86	0.52
	DUMP	6.069	2.655	2.49	0.67
	RETURN	6.318	5.245	4.01	2.42

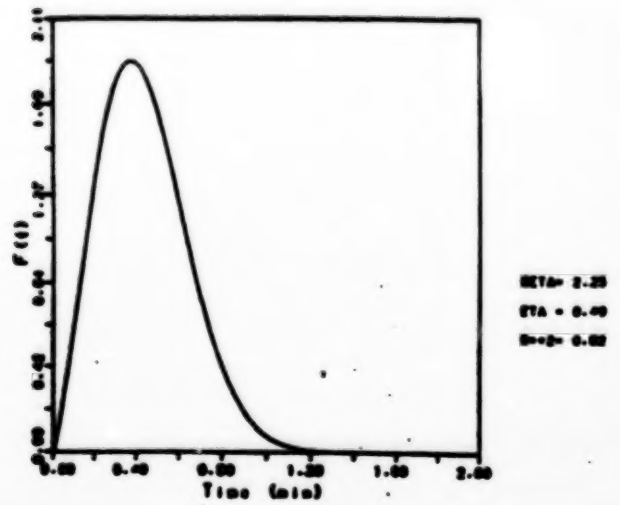


Fig. 5 Weibull p.d.f. of truck spotting times.

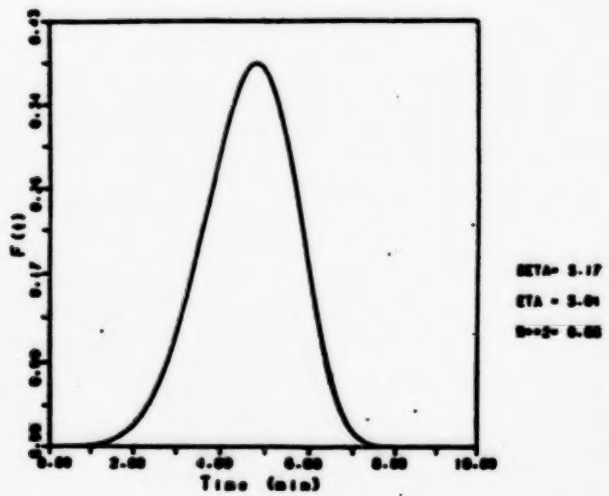


Fig. 6 Weibull p.d.f. of truck loading times.

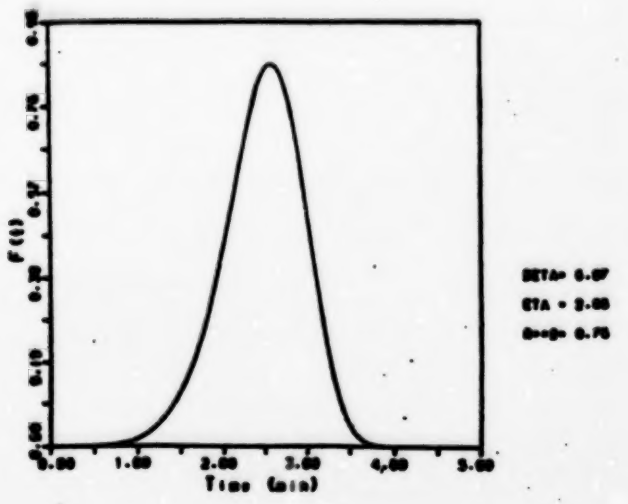


Fig. 7 Weibull p.d.f. of truck dumping times.

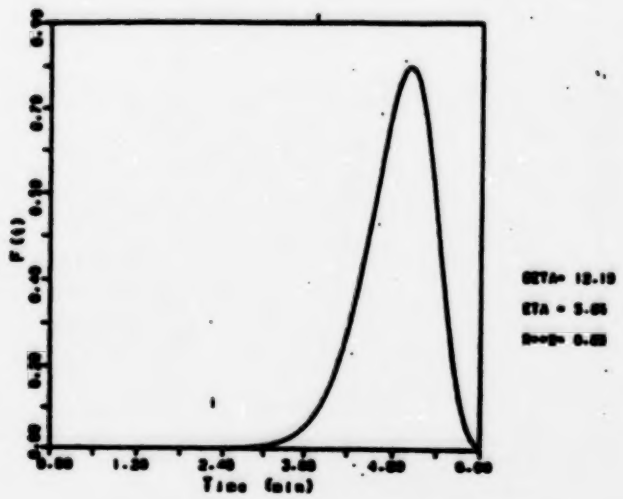


Fig. 8 Weibull p.d.f. of truck hauling times.

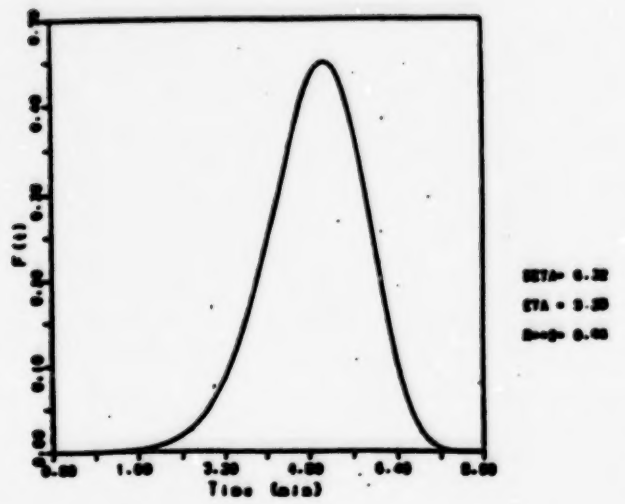


Fig. 9 Weibull p.d.f. of truck return times.

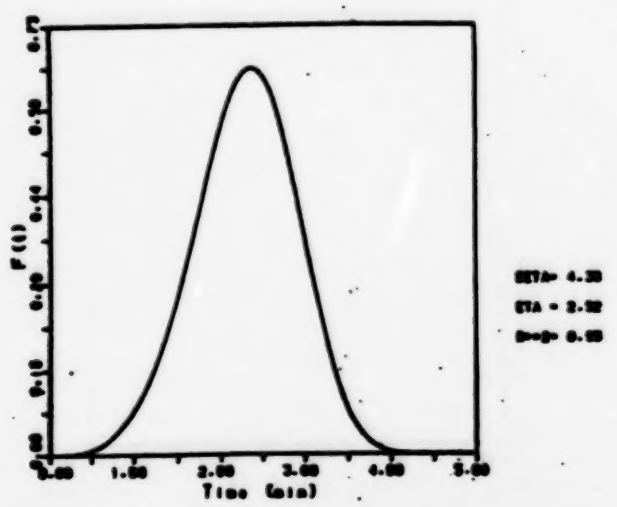


Fig. 10 Weibull p.d.f. of CSM turnaround times.

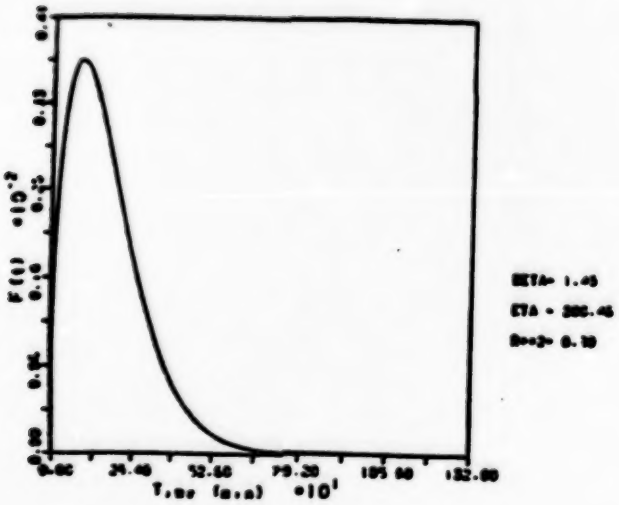


Fig. 11 Weibull p.d.f. of CSM times to repair (TTR).

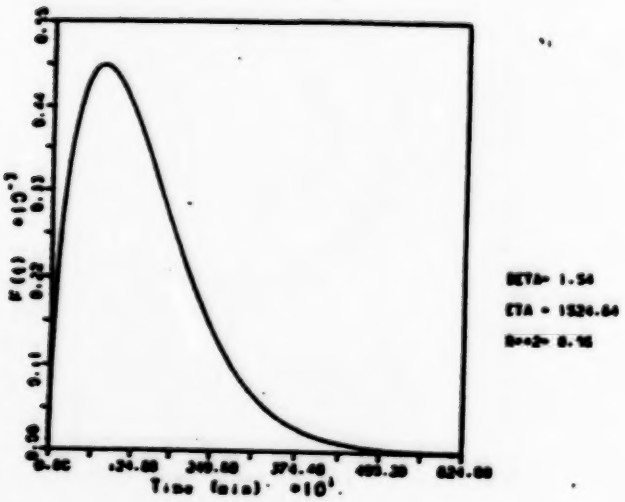


Fig. 12 Weibull p.d.f. of CSM times to failure (TTF).

COMPUTER MODEL OF THE CSM AND TRUCKS HAULAGE SYSTEM

The simulation language SLAM II (Simulation Language for Alternative Modeling) was used to develop the model. SLAM II is an advanced FORTRAN based language that allows simulation models to be built using networks in which are embedded both discrete event and continuous procedures (1).

In this example the coal extraction operation of an open pit mine is modelled. The mining is done by advancing a continuous type mining machine forward, while undercutting the mined layer with a rotating cutter. Mined out coal is pushed onto an intermediate conveyor, which in turn transfers it to a pivot-mounted load-out conveyor. Fig. 13 illustrates the wide-surface mining method which is hallmarked by mining the exposed coal, layer after layer, in strips adjacent to each other. The length of each strip was equivalent to three 90 tonne truckloads.

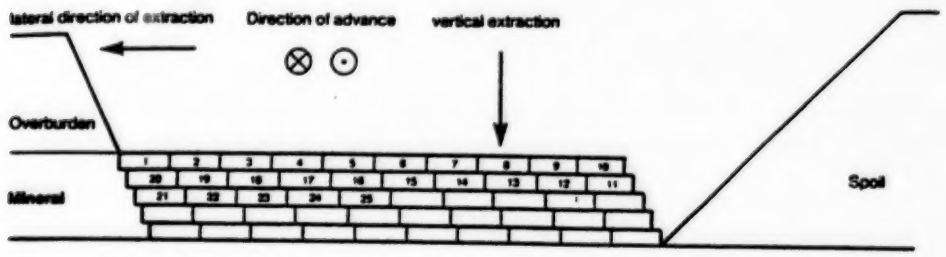


Fig. 13 Wide-surface mining method.

In the mine, loaded trucks deliver the coal from the CSM to a crusher. A truck always returns to the CSM after dumping a load at the crusher. Three rear dump Wabco trucks with coal box capacity of 90t were assigned to the CSM during the field survey.

SLAM II MODEL

The entities to be modelled are a number of trucks and one CSM. As the problem emphasis is on the productivity of this particular loading system the trucks were considered unfailing entities that cycle to the loader. The loading entity however was modelled as a resource which was available to the trucks for loading except when delayed by turn around at the end of cut or by machine failure.

The SLAM II graphical model for this system is shown in Figure 14. Each truck is assigned two attribute values consisting of 1) a component of the time cycle; and 2) truck tonnage (90t). Note that entities are neither created or terminated within the graphical model. Therefore, to initiate the simulation, we must insert trucks directly into the network. These entities will continue to cycle through the network until the simulation is terminated. However, before discussing the procedure for inserting these entities into the network, we will complete the description of the network model. We begin our description at the far left COLCT node labeled STRT. Entities arriving to the node STRT represent trucks completing their return trip from the crusher. The COLCT node STRT collects statistics on the value of truck return times. One identifies the statistical output with the label TRK_RET_TIME. Prepare a histogram consisting of 30 cells, each of which will have the width of 0.25 (See Fig. 18). The load time is assigned to attribute 1 at an ASSIGN node. The estimated load times have Weibull distribution with parameters given in table 1. In this place, conditional branching is specified from the ASSIGN node where M-number is one, that is, a maximum of one of the two branches emanating from the ASSIGN node is to be taken. The truck is routed to node AWT; if the number of entities (trucks) in activity 1 (loading) is equal to zero, or number of entities in activity 2 (turnaround of CSM) is equal to 0. No condition is specified on the branch from the ASSIGN node to the next ASSIGN node. Since the conditions are evaluated in the order prescribed by the statement model, this branch will only be taken if the preceding branch is not taken. In this case the load time and spot time is assigned to attribute 1. In this model, the RESOURCE block CSM

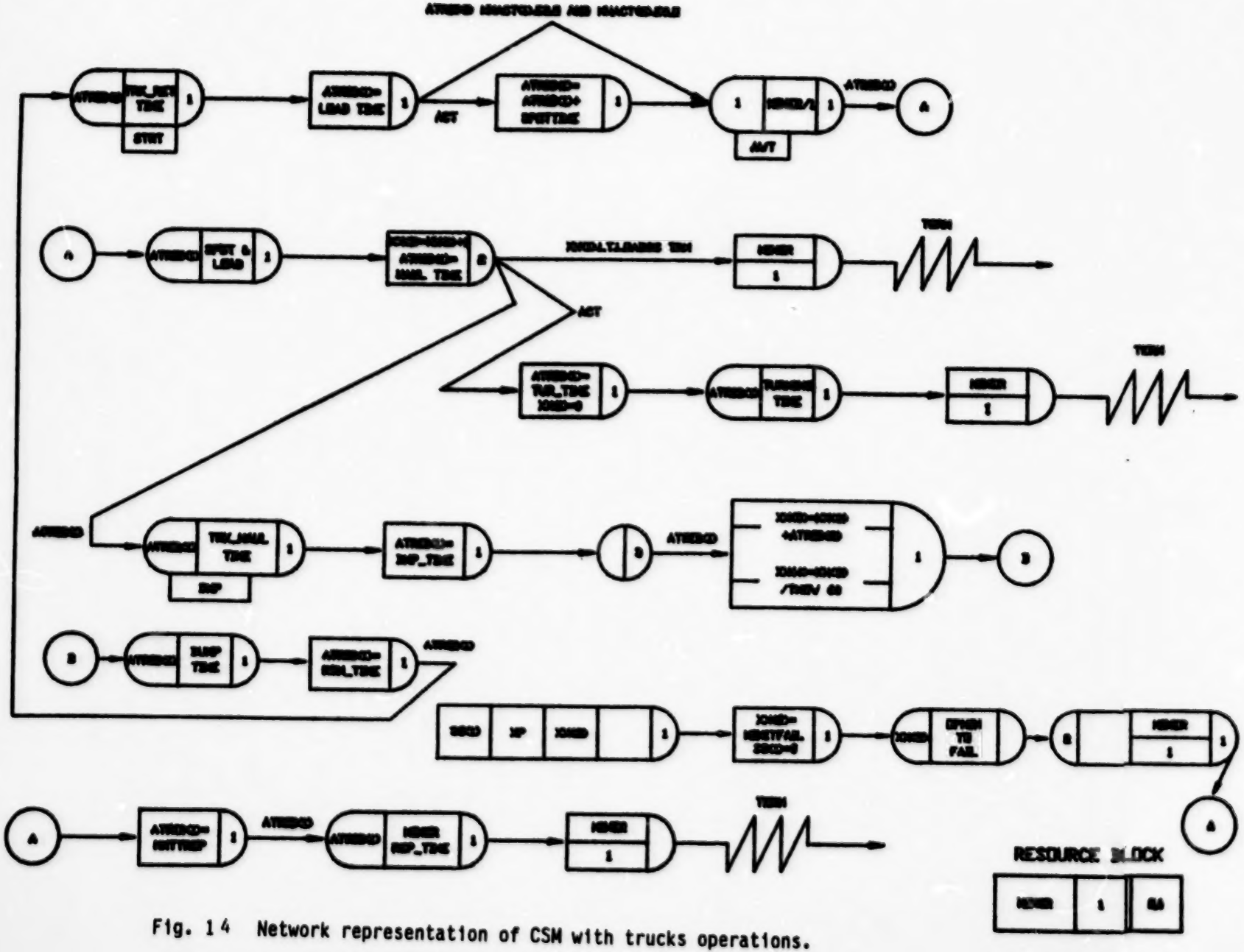


Fig. 14 Network representation of CSM with trucks operations.

indicates that the resource MINER has an initial capacity of one and that it is allocated to the truck at an AWT node where file 1 and 2 is used to maintain waiting trucks. A truck is removed from the file associated with AWAIT node when unit of the resource (CSM) required by the truck can be assigned to it. At the COLCT node the statistics on the value of truck spot and load times are collected. The value of the load counter XX(1) is incremented by one at an ASSIGN node, and the value of attribute 1 passing through this node is changed to truck haul times, whose distribution is Weibull. Conditional branching is specified from the ASSIGN node where the M-number is two, that is, a maximum of two of the three branches emanating from the ASSIGN node is taken. The resource (CSM) is released at the FREE node TEM if the load counter is less than three (three trucks have to be loaded before CSM turns around to mine another strip of coal). The branch from ASSIGN node to another ASSIGN node is taken if the load counter is greater than 3. In this case, the TUR-TIME is assigned to attribute 1 and the easi-miner has to turn-around for another cut before it is freed for further loading of trucks.

After completing the hauling operation, the truck is routed to the COLCT node DMP where the statistics on the value of truck haul times are collected. The dumping time is assigned to attribute 1 of the next ASSIGN node. The entity continues to a QUEUE node representing the queue of trucks waiting to dump coal at the crusher. Trucks in the QUEUE node are waiting for the CRUSHER in file 3. The dumping operation is represented by the service ACTIVITY emanating from the QUEUE node and has also Weibull distribution. Following completion of the dumping operation, the entity arrives to the ASSIGN node where the value of the production counter XX(3) is set to attribute 2 (truck tonnage). The second assignment specifies that XX(4) be given a value that is a production rate (throughput) of the system. The value of M is set to 1 to indicate that the entity is to be routed through only one branch. The truck continues to the next COLCT node where dump times statistics are recorded. The entity then continues through the emanating ACTIVITY representing the return trip. The value of return time has been assigned to attribute 1 at the last ASSIGN node. The return ACTIVITY has a duration given by a Weibull distribution, and routes the entity back to the COLCT node labelled STRT.

The initial insertion of truck entities into the network is accomplished by the ENTRY statements. The ENTRY statements place three trucks into file 3 (QUEUE) with attribute values (2.50, 90), (2.50,90) and (2.50, 90). These entities correspond to three 90 ton trucks. Since file 3 is a queue for a crusher, the filing of an entity into file 3 is processed as an arrival to that node.

The CSM experiences breakdowns during which time it can no longer perform mining and loading operations. When a breakdown occurs, the entity being processed is removed from service and it is placed in file 2. Trucks pre-empted restart from the point at which they were interrupted.

The second network segment illustrates the processing of the resource breakdown situation. The SLAM II state variable SS(1) issued to represent time between failures. Continuous change of the state variable SS(1) is defined in terms of the different equations in subroutine STATE in the following fashion: (SS(1) = SSL(1) + DTNOW*OPRT where DTNOW is the step size and OPRT=1 or 0 specifies the rate of change of state variable SS(1) during DTNOW. A DETECT node is used in a network to describe the conditions for a state event, and provides the primary interface between the continuous and network portions of the model. When SS(1) crosses XX(2) in a positive direction, which has a value of time between failure (sample from Weibull distribution), the node is released and the truck is routed to a PREEMPT node where the resource (CSM) MINER is captured. The value of the time to repair is assigned to attribute 1. Following repair, the easi-miner is made available by routing it through a FREE node.

The statement model for this simulation is shown in Figure 15. Figure 16 shows a FORTRAN listings of FUNCTION WEIBL and SUBROUTINE STATE.

```
GEN,GRIFSZY,CSM,12/04/86,1,Y,N,Y,N,Y,72;
LIMITS,3,2,90;
CON,,1,.01,5;
RECORD,TNOW,CSM,0,P;
VAR,SS(1),M,CSM;
TIMST,XX(4),PROD_TPERHR;
EQU/3,LOADS_TRN/;
EQU/WEIBL(.491,2.252),SPOT_TIME/WEIBL(5.015,5.165),LOAD_TIME/;
EQUIVALENCE/WEIBL(2.521,4.383),TURN_TIME/;
EQUIVALENCE/WEIBL(132.42,240.),MNTTFAIL/WEIBL(6.120,.897),MNTTREP/;
EQUIVALENCE/WEIBL(5.058,12.189),HAUL_TIME/WEIBL(2.655,6.069),DMP_TIME/;
EQUIVALENCE/WEIBL(5.245,6.318),RTN_TIME/;
INTLC,XX(1)=0,XX(2)=120,XX(3)=0:LOAD COUNTER,FIRST FAILURE TIME & PROD SUMMER
SEEDS,7765403(9);
NETWORK;
       RESOURCE/MINR(1),2,1;
STRT   COLCT,ATRIB(1),TRK_RET_TIME,30/1/.25;
       ASSIGN,ATRIB(1)=LOAD_TIME,1;
       ACT,,NNACT(1).EQ.0.AND.NNACT(2).EQ.0,AWT;
       ACT;
       ASSIGN,ATRIB(1)=ATRIB(1)+SPOT_TIME;
AWT    AWAIT(1),MINR/1;   AWAIT THE CSM
       ACT/1,ATRIB(1);SPOT & LOAD     TRUCK
       COLCT,ATRIB(1),SPOT & LOAD,30/1/.25;
       ASSIGN,XX(1)=XX(1)+1,ATRIB(1)=HAUL_TIME,2; SUM LOADS TO TURNAROUNC
       ACT/6,ATRIB(1),,DMP;HAULING        TO THE DUMP
       ACT,,XX(1).LT.LOADS_TRN,TRM;
       ACT;
       ASSIGN,ATRIB(1)=TURN_TIME,XX(1)=0;
       ACT/2,ATRIB(1);TURNAROUND
       COLCT,ATRIB(1),TURNING_TIME,30/1/.1;
TRM    FREE,MINR/1; FREE CSM
       TERM;
       DETECT,SS(1),XP,XX(2),1.; RUN TIME TO FAILURE OF CSM
       ASSIGN,XX(2)=MNTTFAIL,SS(1)=0.,1;RESET FAIL TIME AND OP TIMER
       COLCT,XX(2),OPMIN_TO_FAIL,30/100/4;
       PREEMPT(2),MINR;  TAKE THE CSM OUT OF SERVICE
       ASSIGN,ATRIB(1)=MNTTREP;
       ACT/3,ATRIB(1);REPAIR CSM
       COLCT,ATRIB(1),CSM_REP_TIME,30/0/.25;
       FREE,MINR;     PUT THE CSM BACK IN SERVICE
       TERM;
DMP    COLCT,ATRIB(1),TRK_HAUL_TIME,30/2/.25;
       ASSIGN,ATRIB(1)=DMP_TIME;
       QUE(3);
       ACT(2)/4,ATRIB(1); DUMPING
       ASSIGN,XX(3)=XX(3)+ATRIB(2),XX(4)=XX(3)/TNOW*60.;CALC T/HR TO DATE
       COLCT,ATRIB(1),DUMP_TIME,30/1/.25;
       ASSIGN,ATRIB(1)=RTN_TIME;
       ACT/5,ATRIB(1),,STRT; RETURNING
       END;
INIT,0,1000;
ENTRY/3,2.50,90;
ENTRY/3,2.50,90;
ENTRY/3,2.50,90;
FIN;
```

Fig. 15 Statement model of CSM with trucks operations.

```
C
      FUNCTION WEIBL(BETA,ALPHA,ISD)
      WEIBL=BETA*ABS(ALOG(DRAND(ISD)))**(1./ALPHA)
      RETURN
      END
      SUBROUTINE STATE
      COMMON/SCOM1/ ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C TO KEEP TRACK OF OPERATING TIME OF THE CSM
      OPRT=0.
      IF(NNACT(1).EQ.0.AND.NNACT(2).EQ.0)GO TO 1
      OPRT=1.
1     SS(1)=SSL(1)+DTNOW*OPRT
      RETURN
      END
```

Fig. 16 FORTRAN listings of FUNCTION WEIBL and SUBROUTINE STATE.

SUMMARY OF RESULTS

The results for this simulation are summarized in the SLAM II, Summary Report shown in Figure 17.

The first category of statistics for this run are statistics for variables based on observations. They consist of the interval statistics on the truck cycle components collected by the COLCT statements.

The second category of statistics for this simulation is the time-persistent variables. It consists of the production rate in t/hr expressed in operating time for the system in question. During the 100,000 minutes of simulated operaton the system production rate was of 848.62 t/hr of coal. Validation against production data from an operating mine has shown that the model describes this system performance reasonably well.

The next category of statistics is the file statistics. The statistics for file 1 and 2 correspond to the trucks waiting to be loaded at the CSM. The statistics for file 3 correspond to the trucks waiting for a service at a crusher side (dump). In addition to the above statistics,

statistics are also provided on each numbered ACTIVITY in the regular activity statistics. The final category of statistics are the service activity statistics, and resource (CSM) statistics corresponding to the average resource utilization.

The example distribution for trucks return times is depicted by the histogram generated by SLAM II and included as Figure 18.

REFERENCES

1. Pritsker, A., Alan B. "Introduction to Simulation and SLAM II"; New York: Halsted Press (a division of John Wiley & Sons), and West Lafayette, Indiana: Systems Publishing Corporation, 1986.

2. Michael, J.E. "The Stabilized Probability Plot"; Biemetrika; 70.1.pp. 11-17; 1983.

SLAM II SUMMARY REPORT

SIMULATION PROJECT — BY GRIFFIN

DATE 12/ 4/1986 — RUN NUMBER 1 OF 1

CURRENT TIME 0.1000E+05
STATISTICAL ARRAYS CLEARED AT TIME 0.0

--STATISTICS FOR VARIABLES BASED ON OBSERVATION--

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO. OF OBS
TRK_RET_TIME	0.4888E+01	0.8848E+00	0.1810E+00	0.8810E+00	0.7748E+01	*****
SPOT & LOAD	0.4888E+01	0.1088E+01	0.2178E+00	0.9838E+00	0.8888E+01	*****
TURNING_TIME	0.2318E+01	0.8888E+00	0.3838E+00	0.2878E+00	0.3888E+01	5237
OPNIN_TO_FAIL	0.1338E+03	0.7118E+00	0.5318E-02	0.1288E+03	0.1348E+03	888
MINER_REP_TIME	0.7838E+01	0.8888E+01	0.1148E+01	0.1888E-02	0.8218E+02	888
TRK_HAUL_TIME	0.4888E+01	0.4878E+00	0.1888E+00	0.2238E+01	0.8108E+01	*****
DUMP_TIME	0.3488E+01	0.4748E+00	0.1828E+00	0.4288E+00	0.3778E+01	*****

--STATISTICS FOR TIME-PERSISTENT VARIABLES--

	MEAN VALUE	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	TIME INTERVAL	CURRENT VALUE
PROD_TPERHR	847.255	34.827	0.0	4330.00	**********	848.82

--FILE STATISTICS--

FILE NUMBER	ASSOC LABEL/TYPE	NODE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	AWT	AWAIT	0.323	0.810	3	0	2.058
2		PREEMPT	0.0	0.0	0	0	0.0
3		QUEUE	0.000	0.005	1	0	0.000
4		CALENDAR	2.828	0.958	5	3	2.108

--REGULAR ACTIVITY STATISTICS--

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 SPOT & LOAD	0.7854	0.4230	1	1	15713
2 TURNAROUND	0.1201	0.3250	1	0	5237
3 REPAIR MINER	0.0488	0.2115	1	0	888
5 RETURNING	0.7850	0.5380	3	1	15714
6 HAULING	0.7588	0.5000	2	1	15712

--SERVICE ACTIVITY STATISTICS--

ACT NUM	ACT START NODE	LABEL OR	SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX IDL TIME/SER	MAX BSY TIME/SER	ENT CNT
4	DUMPING		2	0.385	0.48	0	0.0	2.00	2.00	*****

--RESOURCE STATISTICS--

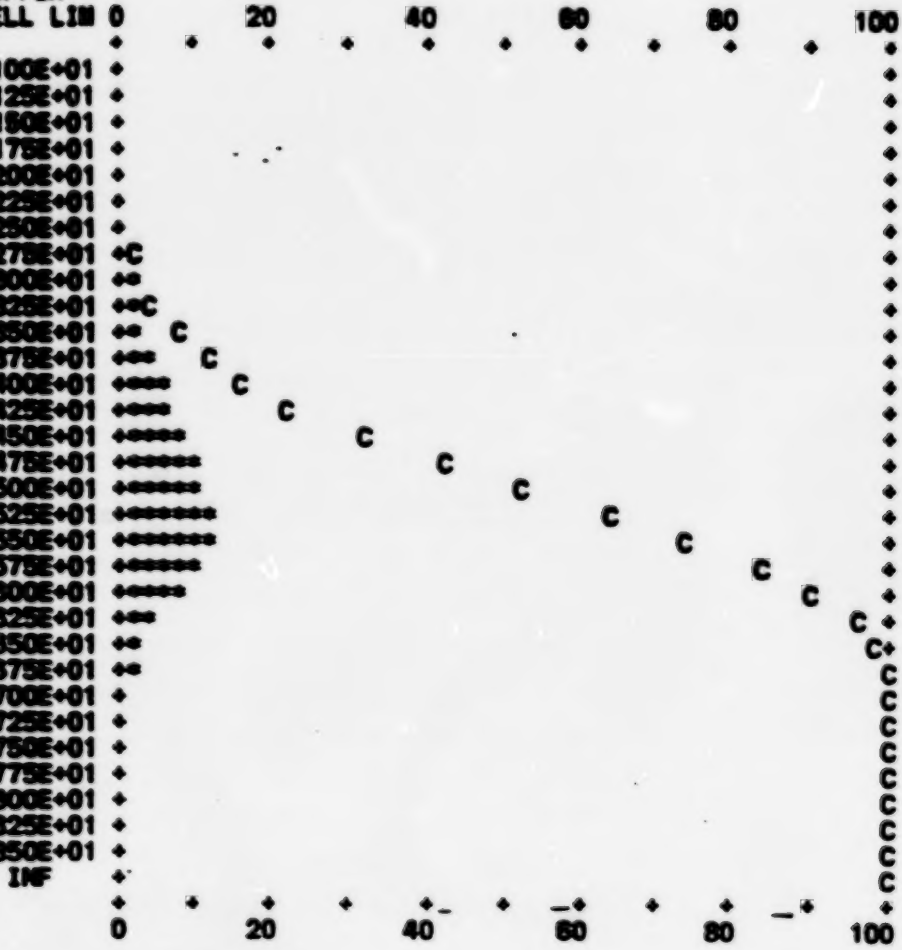
RESOURCE NUMBER	RESOURCE LABEL	CURRENT CAPACITY	AVERAGE UTIL	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL
1	MINR	1	0.83	0.251	1	1

RESOURCE NUMBER	RESOURCE LABEL	CURRENT AVAILABLE	AVERAGE AVAILABLE	MINIMUM AVAILABLE	MAXIMUM AVAILABLE
1	MINR	0	0.0875	0	1

Fig. 17 SLAM II, Summary report for CSM with trucks in open pit operations.

HISTOGRAM NUMBER 1
TRK_RET_TIME

OBS FREQ	RELA FREQ	UPPER CELL LIM
1	0.000	0.100E+01
2	0.000	0.125E+01
0	0.0	0.150E+01
11	0.001	0.175E+01
24	0.002	0.200E+01
31	0.002	0.225E+01
84	0.004	0.250E+01
118	0.008	0.275E+01
181	0.012	0.300E+01
275	0.018	0.325E+01
458	0.029	0.350E+01
601	0.038	0.375E+01
798	0.051	0.400E+01
***	0.064	0.425E+01
***	0.086	0.450E+01
***	0.101	0.475E+01
***	0.107	0.500E+01
***	0.111	0.525E+01
***	0.110	0.550E+01
***	0.082	0.575E+01
***	0.070	0.600E+01
740	0.047	0.625E+01
417	0.027	0.650E+01
227	0.014	0.675E+01
80	0.005	0.700E+01
21	0.001	0.725E+01
5	0.000	0.750E+01
1	0.000	0.775E+01
0	0.0	0.800E+01
0	0.0	0.825E+01
0	0.0	0.850E+01
0	0.0	INF



STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
TRK_RET_TIME	0.488E+01	0.894E+00	0.183E+00	0.691E+00	0.774E+01	****

Figure 18 SLAM II histogram for times to return (trucks).